SUITABLILITY OF HOUSEHOLD SOLID WASTE FOR CONVERSION TO ENERGY: A CASE STUDY OF JIMETA/YOLA, NIGERIA

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Abstract--The study was carried out to determine whether the municipal solid waste generated in Yola metropolis would be suitable for energy production. The study area was classified into three different waste areas, namely waste areas A, B, and C known as high, medium, and low income areas, respectively. Ten households were selected at random from each waste area for the analysis of the waste. Site specific study method was used to characterize the waste, whereas the calorific value of the waste was determined by experiment using laboratory bomb calorimeter. The results obtained from the study showed that the waste generation per capita per day was 0.37kg/cap/day, 0.25 kg/cap/day, 1.72 kg/cap/day for waste areas A, B, and C respectively and that 75-90% of the municipal solid waste in Yola metropolis was of organic materials. The average moisture content analysis was found to be 61.33% whereas the calorific value was calculated at 3056.6kJ/kg. These results show that the municipal solid waste in Yola metropolis is of high moisture content and low calorific value indicating that the waste may not be suitable for use in energy production. However, it is recommended that since the municipal solid waste could not be suitable for energy production, it should be used for composting as viable recovery alternative; and also further research be carried out on annual basis for some number of years in order to take care of both short-term (seasonal) and long-term (e.g. 5 years period) variations in waste characteristics.

Keywords: Municipal solid waste, Energy Production, Waste Generation, Calorific Value, Yola, Metropolis, Calorific Value.

1.0 INTRODUCTION

Human activities generate wastes in large quantity that are often discarded in different locations across Nigerian cities due to the inability of authorities to manage such wastes in a sustainable way as a result of inadequate knowledge and institutional or financial framework. This leads to environmental degradation. It also leads to the spread of diseases by insects or birds due to uncontrolled landfills.

But many of these waste materials can be reused and thus, can become a resource for industrial production or energy production, if properly managed.

The potential of biogas production using municipal solid waste in Nigeria was studied [1]. But this study focuses on the potentials of household solid wastes in Jimeta /Yola metropolis of Adamawa state, Nigeria to see its suitability for energy production and also as a means of minimising environmental pollution.

2.0 MATERIALS AND METHODS

2.1. The Study Area

The study was conducted in Jimeta – Yola metropolitan which falls within the north guinea savannah region and it is both the political and administrative capital of Adamawa State. It is the largest and most populated of the 21 urban centres in the state with an estimated population of 159,779 persons in 1991 to 234,472 in 2006 [2]. The study area was classified into three waste area types, namely high (Area A), medium (Area B), and low (Area C) population density waste areas for the purpose of conducting this work. This was done on the assumption that there is a significant positive correlation between per capita waste generation and income levels of the residents [3].

2.2 Collection of Waste Samples for Quantification

For preparation and analysis, municipal solid waste samples were collected from ten houses selected randomly from each waste area. The collection was done on daily basis for period of ten days using the National guidelines on Environmental Health Practice in Nigeria [4].

2.3 Sampling Method

To determine the waste composition, hand sorting of the waste samples was used. After collection of the waste samples from the households in the classified waste areas; the samples were then pooled together to form a huge waste composite sample.

The composite sample was then sorted by hand according to the following categories: - Paper, Plastics, Rubber, Textiles, Leather, Glass, Metals, and Organic/others. At the completion of the sorting, each category was placed in its appropriate container and weighed. The various weights of the different wastes categories were recorded in the data sheet.

2.4 Moisture Content Determination

Waste samples were extracted from a representative composite sample in each waste area. The samples were weighed as collected (wet weight) and allowed to stay under the sun for 24hrs until it became fairly dry. 1kg of the partially dried samples was again extracted and placed into a preheated (hot-air) oven set at 105℃ for 2hrs. The heated or dried sample was then removed, cooled and weighed (dry weight). The weights of the wet and dry weights were then recorded.

The percentage moisture content for the waste in each waste area was then obtained through the following formula:

$$\text{Moisture Content}, M_C\ (\%) = (W_W - W_D) / W_W \times 100\% \quad (3.2)$$

Where W_W = weight of wet sample (kg)

W_D = weight of dry sample (kg)

2.5 Determination of Calorific Value

The Calorific value represents the energy actually available to be converted into heat and/or electricity [5]. It was determined through experimental analysis by a bomb calorimeter (Parr 1241) according to ASTM D5468.

The calorific value was then calculated using the following formula:

$$\text{C.V.} = \frac{\Delta T \times W - e}{m} \quad [7].$$

3.0 RESULTS

3.1 Waste Generated Per Capita

Table 1 shows the comparison between wastes generated per capita per day in the various waste areas.

Table 1: Comparison between the Per Capita Waste Generations in the Waste Study Areas.

Waste Area	Waste generated (kg/cap/day)										
	Days										
	1	2	3	4	5	6	7	8	9	10	Ave
A	0.59	0.15	0.54	0.61	0.5	0.46	0.28	0.17	0.26	0.17	0.37
B	0.3	0.31	0.37	0.22	0.16	0.13	0.24	0.4	0.24	0.11	0.25
C	2.45	1.64	1.82	1.46	1.36	1.59	1.72	1.72	1.39	2.03	1.72

Figures 1, 2, and 3 show how waste generation varies with days of the week with respect to the various waste areas.

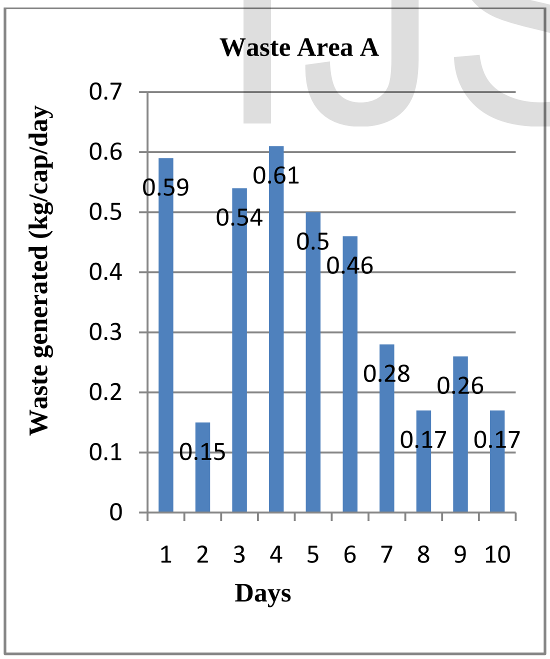

Fig.1 Waste Generation Rate for Area A

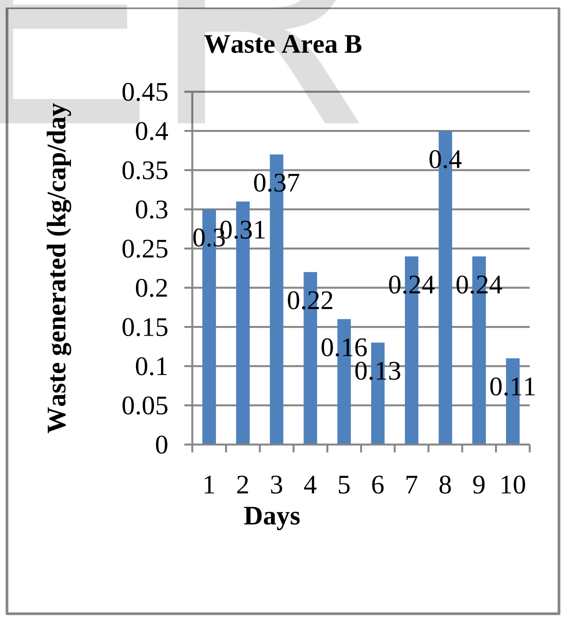

Fig.2 Waste Generation Rate for Area B

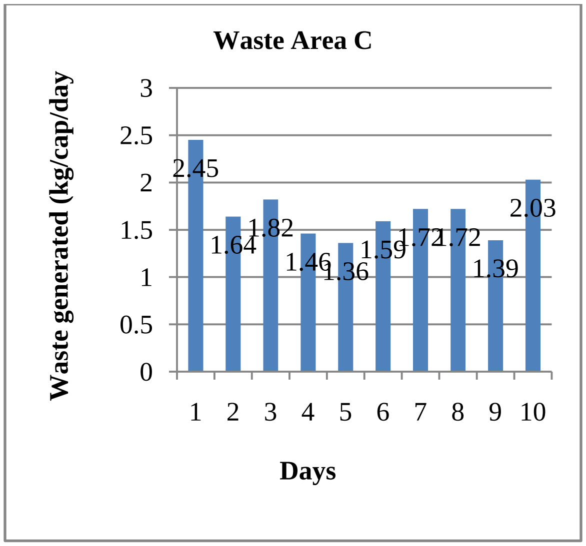

Fig.3 Waste Generation Rate for Area C

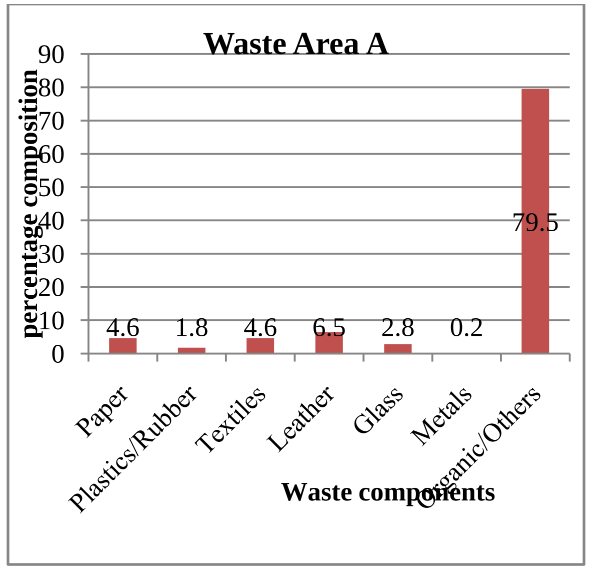

Fig.4: Percentage waste composition for waste area A

3.1 Composition of Municipal Solid Waste (MSW)

The percentage compositions of the components in the various waste areas were presented in table 2.

Table 2: Composition (%) of the Waste Components in various areas.

Paper	4.6	0.9	1.3
Plastics/Rubber	1.8	0.3	0.8
Textiles	4.6	1.7	1.2
Leather	6.5	5.7	3.8
Glass	2.8	2.3	0.8
Metals	0.2	0.3	0.4
Organic/Others	79.5	88.8	91.7
Total	100	100	100

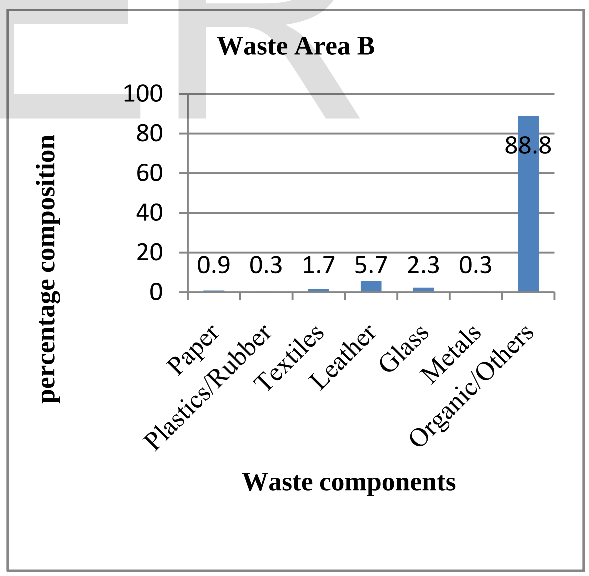

Fig.5: Percentage waste composition for waste area B

The percentage waste composition of different waste components for each waste area is presented in figures 4, 5, 6.

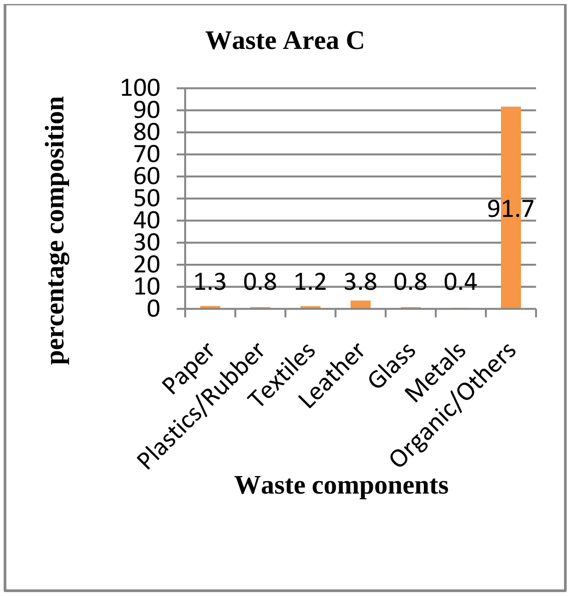

Fig. 6: Percentage waste composition for waste area C

3.3 Moisture Content of the Municipal Solid Waste

The results of the moisture content of the wastes in the various waste areas are as shown in fig 7.

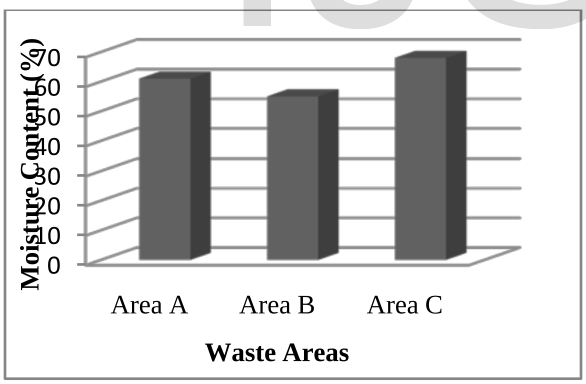

Fig.7: Moisture contents of MSW in the various waste areas.

3.4 Calorific Value of the Waste

The calorific values of the municipal solid wastes in the various waste areas were determined by using bomb calorimeter [11]. The results obtained from the bomb calorimeter were presented in tables 3, 4, 5 where * and ** represent the time when firing starts and the maximum temperature reached respectively.

TABLE 3: Time and Temperature readings for Waste Area A

Time(min)	Mass of Sample=0.8g	Mass of Sample=0.7g	Mass of Sample=0.9g
	Temperature(0C)	Temperature(0C)	Temperature(0C)
0	20.56	20.85	21.03
1	20.57	20.86	21.04
2	20.58	20.87	21.05
3	20.59	20.9	21.07
4	20.61	20.91	21.08
5	20.7*	20.92*	21.10*
6	21	20.98	21.25
7	21.15	21.15	21.27
8	21.22	21.17	21.31
9	21.31	21.25	21.35
10	21.32	21.27**	21.36
11	21.34	21.27	21.4**
12	21.35**	21.27	21.4
13	21.35	21.27	21.4
14	21.35		21.4
15	21.35		21.4

TABLE 4: Time and Temperature readings for Waste Area B

Time(min)	Mass of Sample=0.8g	Mass of Sample=0.7g	Mass of Sample=0.9g
	Temperature(0C)	Temperature(0C)	Temperature(0C)
0	20.56	20.85	21.03
1	20.57	20.86	21.04
2	20.58	20.87	21.05
3	20.59	20.9	21.07
4	20.61	20.91	21.08
5	20.7*	20.92*	21.10*
6	21	20.98	21.25
7	21.15	21.15	21.27
8	21.22	21.17	21.31
9	21.31	21.25	21.35
10	21.32	21.27**	21.36
11	21.34	21.27	21.4**
12	21.35**	21.27	21.4
13	21.35	21.27	21.4
14	21.35		21.4
15	21.35		21.4

TABLE 5: Time and Temperature readings for Waste Area C

Time(min)	Mass of Sample=0.8g	Mass of Sample=0.9g	Mass of Sample=0.85g
	Temperature(0C)	Temperature(0C)	Temperature(0C)
0	20.34	20.38	20.62
1	20.35	20.4	20.63
2	20.37	20.41	20.64
3	20.38	20.42	20.65
4	20.39	20.43	20.66
5	20.42*	20.45*	20.69*
6	20.44	20.46	20.82
7	20.48	20.62	20.95
8	20.69	20.72	20.98**
9	20.7	20.75	20.98
10	20.71	20.75	20.98
11	20.71	20.76**	20.98
12	20.72**	20.76	
13	20.72	20.76	
14	20.72	20.76	
15	20.72		

The patterns of temperature change for the samples in the three waste areas are as shown in figure 8, 9, and 10.

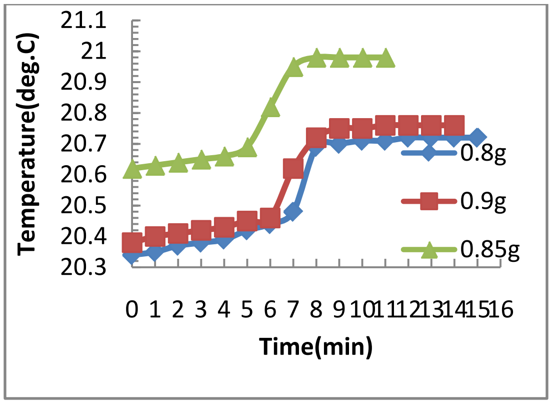

Fig.8: Temperature rise vs. Time for Waste Area A

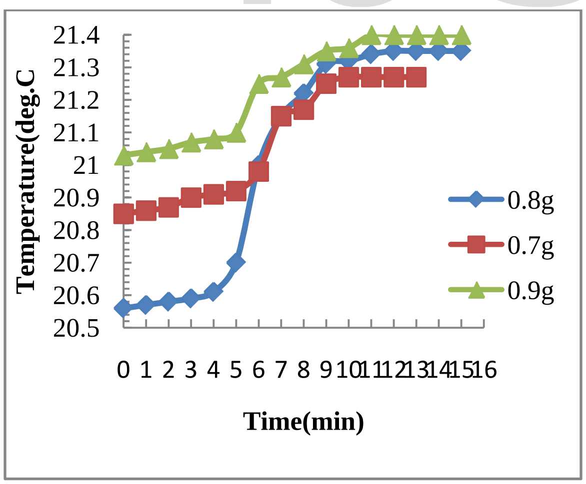

Fig.9: Temperature rise vs. Time for Waste Area B

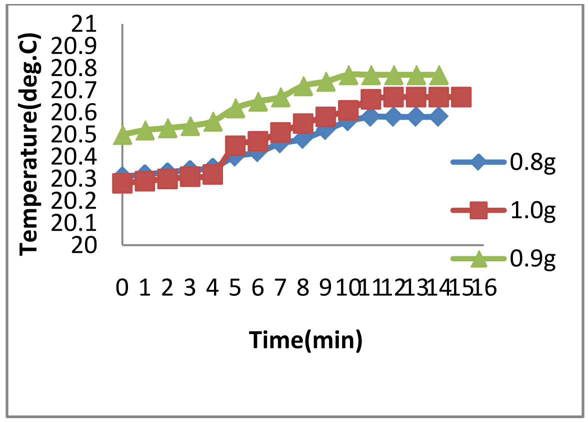

Fig.10: Temperature rise vs. Time for Waste Area C

From the temperature - time graphs (figs. 8-10) it is observed that for the first 5 minutes of experiment, the temperature increased slowly as the firing within the bomb calorimeter began, followed by rapid temperature rise.

The calorific values for the three waste areas (A, B, and C) are presented in figure 11.

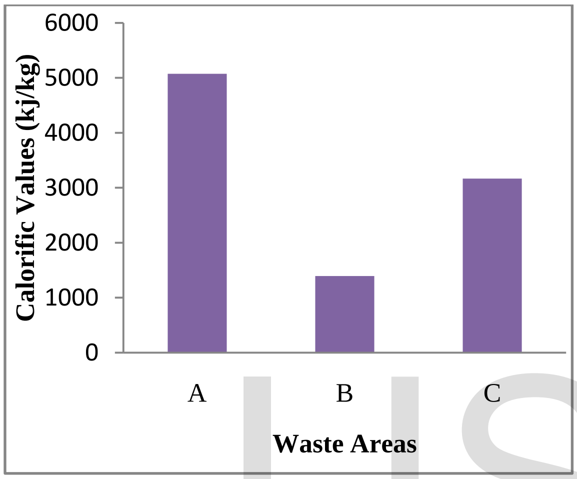

Fig. 11: Calorific values of MSW in the various waste areas

4.0 DISCUSSION

In waste area A (Fig. 1), the per capita generation is the highest on day 4 (0.61kg/cap/day) and lowest on day 2 (0.15kg/cap/day) over the collection period. For waste area B (Fig. 2), the per capita generation rate is higher on day 8 (0.4kg/cap/day) and lower on day 10 (0.11kg/cap/day) than the other days. Also, in waste area C (Fig. 3), the highest rate of waste generated was recorded on the first day of collection (2.45kg/cap/day) while the lowest rate was obtained on the day 5 (1.36kg/cap/day).

From table 1, it can be seen that the average waste generation per capita per day is higher in waste area C (1.72kg/cap/day), followed by waste area A (0.37kg/cap/day), while it is lower in waste area B (0.25kg/cap/day). This difference could be due to the variations in standard of living of the people in those areas, population growth and probably due to activities of scavengers.

On average basis, the estimated generation rate of 6.75kg/cap/day was found for Yola (Jimeta) metropolis. This shows an increase when compared to that of 0.6kg/cap/day and 0.65kg/cap/day for Jimeta-Yola as obtained by[8]and [9]respectively.

On daily basis, it can be seen from table 1 that least waste generated per capita was between 0.11kg/cap/day obtained in area C and the highest was 2.45kg/cap/day was obtained in area C throughout the period of investigation.

From the table, it can be seen that organic wastes constitute the major constituent of the waste in all the waste areas under the study with 79.50%, 88.8%, and 91.7% in areas A, B, and C respectively. This indicates that the low income area produced waste of more organic content. This is in line with the findings of [10], who reported that in developing countries, waste stream is constituted of over 50% organic material.

From fig.7 above, the highest percentage of the moisture content is 68.0% for waste from waste area C; followed by 60.50% for waste area A. Waste area B has the lowest percentage of moisture content (55.0%).

The values obtained are high and indicate that the waste in the study area is very wet. The high values of the moisture content might be due to the large quantity of wet materials such as the organic components in the waste stream. The average of moisture content analysis for the study waste area is 61.33%. This suggests that the moisture content of the municipal solid waste of Jimeta –Yola metropolis is high, probably due to the high content of organic materials present in the waste.

The results shown in Fig. 11 indicate that the calorific value of the waste in area A (4800.9KJ/Kg) was the highest followed by waste area C (3016.3KJ/Kg) while waste area B has the lowest value of 1352.7KJ/Kg). According to the results, the highest calorific value was obtained from the area with highest percentage of plastics. This trend may be caused by the fact that residents in waste area A disposed off wastes with high amounts of caloric value; whereas, residents in waste area B disposed off waste with least amounts of calorific value. The values indicate that the average value of calorific value of the waste in the study area was found to be 3056.6KJ/kg. This value is low compared to that obtained by a researcher who worked on waste generated in Kano city which is 5200KJ/Kg [12] and is below the minimum requirement of 6MJ/kg as set by the World Bank for a municipal solid waste combustion [13]. However, the waste may be used for composting because of high percentage of organic materials.

5.0 CONCLUSION

The municipal solid waste of Yola metropolis was assessed to see its suitability for energy production. The estimated waste generation on per capita basis was found to be averagely 6.75kg/cap/day. It should be noted that the average value is subject to wide variation from season to season and also with the methodology used to estimate the generation rate. The largest portion of municipal solid waste in Yola metropolis as discovered from this study consists of organic materials that were estimated to be 79-90% by weight of the total waste generated. The moisture contents of the wastes in the various waste areas covered during the study were found to be 60.50%, 55.00%, and 68.00% for areas A, B, and C, respectively. The average moisture content of the waste in the study area was found to be 61.33%. This value indicates that the moisture content of waste generated in Yola metropolis is high and this will affect the efficiency of waste processing equipment and also reduce the calorific value of the waste. The calorific value of the waste was found to be 3212.51KJ/Kg on the average, indicating that the municipal solid waste in Yola is of very low calorific value. According to Ogwueleka (2009), high moisture content, low calorific value, and low combustible components of solid waste in Nigeria make incineration uneconomical. Therefore, this study concludes that the municipal solid waste of Yola metropolis may not be suitable for energy production due to the low calorific value as well as high moisture content of the waste.

6.0 RECOMMENDATIONS

It is recommended that since the municipal solid waste could not be suitable for energy production, it should be used for composting as viable recovery alternative. Also, it is recommended that further research be carried out on annual basis for some number of years in order to take care of both short-term (seasonal) and long-term (e.g. 5 years period) variations in the waste characteristics. This will help to have a comprehensive data for the successful design and implementation of a waste management program.

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